U.S. Army Center for Health Promotion and Preventive Medicine

USACHPPM

Epidemiological Study No. 29-HE-3841-99

The Relationship Between Air Particulate Levels and Upper Respiratory Disease in Soldiers Deployed to Bosnia (1997-1998)

Epidemiology Program, Directorate of Epidemiology and Disease Surveillance
U.S. Army Center of Health Promotion and Preventive Medicine
Aberdeen Proving Ground (EA), Maryland 21010-5403

Readiness Thru Health

U.S. Army Center for Health Promotion and Preventive Medicine

The lineage of the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) can be traced back over 50 years. This organization began as the U.S. Army Industrial Hygiene Laboratory, established during the industrial buildup for World War II, under the direct supervision of the Army Surgeon General. Its original location was at the Johns Hopkins School of Hygiene and Public Health. Its mission was to conduct occupational health surveys and investigations within the Department of Defense's (DOD's) industrial production base. It was staffed with three personnel and had a limited annual operating budget of three thousand dollars.

Most recently, it became internationally known as the U.S. Army Environmental Hygiene Agency (AEHA). Its mission expanded to support worldwide preventive medicine programs of the Army, DOD, and other Federal agencies as directed by the Army Medical Command or the Office of The Surgeon General, through consultations, support services, investigations, on-site visits, and training.

On 1 August 1994, AEHA was redesignated the U.S. Army Center for Health Promotion and Preventive Medicine with a provisional status and a commanding general officer. On 1 October 1995, the nonprovisional status was approved with a mission of providing preventive medicine and health promotion leadership, direction, and services for America's Army.

The organization's quest has always been one of excellence and the provision of quality service. Today, its goal is to be an established world-class center of excellence for achieving and maintaining a fit, healthy, and ready force. To achieve that end, the CHPPM holds firmly to its values which are steeped in rich military heritage:

- ★ *Integrity is the foundation*
- ★ *Excellence is the standard*
- ★ *Customer satisfaction is the focus*
- ★ *Its people are the most valued resource*
- ★ *Continuous quality improvement is the pathway*

This organization stands on the threshold of even greater challenges and responsibilities. It has been reorganized and reengineered to support the Army of the future. The CHPPM now has three direct support activities located in Fort Meade, Maryland; Fort McPherson, Georgia; and Fitzsimons Army Medical Center, Aurora, Colorado; to provide responsive regional health promotion and preventive medicine support across the U.S. There are also two CHPPM overseas commands in Landstuhl, Germany and Camp Zama, Japan who contribute to the success of CHPPM's increasing global mission. As CHPPM moves into the 21st Century, new programs relating to fitness, health promotion, wellness, and disease surveillance are being added. As always, CHPPM stands firm in its commitment to Army readiness. It is an organization proud of its fine history, yet equally excited about its challenging future.

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Objective: This study had three objectives: to determine if there is a relationship between air particulate levels and upper respiratory disease in soldiers deployed to Bosnia between 1997-98, to establish a method for linking environmental and military medical data, and to determine ways to improve environmental data collection to improve the ability to anzalyze the data.
Methods: Air particulate level data from the Deployment Environmental Surveillance Program at USACHPPM was linked wiith Disease Non-Battle Injury Data from the Bosnian theatre. The weekly maximum and weekly average PM10 levels for each week were determined. The levels were divided into quartiles, and into upper and lower fiftieth percentiles of exposure. The upper respiratory disease (URD) rates were correlated with exposure groups. The exposure groups were also compared for differences in URD rates using the Kruskal -Wallis and Mann-Whitney tests.
Results: When all camps were combined, there was a statistically significant association between the PM10 Weekly Maximim level and URD rates based on the Kruskal-Wallis and Mann-Whitney tests, and the Pearson correlation was statistically significant. Atlthough the relationship was not statistically significant in the analysis conducted of the individual camps, the average URD rate increased with each quartile of PM10 Weekly Maximum exposure. There was no statistically significant association between PM10 Weekly Average exposure and URD rates, although the average URD rate increased with each quartile of PM10 Weekly Average exposure.
Conclusion: While a causal link cannot be determined from this study, there does appear to be a relationship between PM10 levels and URD rates in soldiers deployed to Bosnia n 1997-1998. This contradicts thinking that soldiers are not likely to suffer effects from short term exposure to air particualtes. The effects of air particulates on soldiers should be investigated further as more environmental data becomes available.

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THE RELATIONSHIP BETWEEN AIR PARTICULATE LEVELS AND UPPER RESPIRATORY DISEASE IN SOLDIERS DEPLOYED TO BOSNIA, 1997-98

1. Objective. This study had three objectives: to determine if there is a relationship between air particulate levels and upper respiratory disease in soldiers deployed to Bosnia between 1997-98, to establish a method for linking environmental and military medical data, and to determine ways to improve environmental data collection to improve the ability to analyze the data.

2. Methods. Air particulate level data from the Deployment Environmental Surveillance Program at USACHPPM was linked with Disease Non-Battle Injury Data from the Bosnian theatre. The weekly maximum and weekly average PM_{10} levels for each week were determined. The levels were divided into quartiles, and into upper and lower fiftieth percentiles of exposure. The upper respiratory disease (URD) rates were correlated with exposure groups. The exposure groups were compared for differences in upper respiratory disease rates using the Kruskal-Wallis and Mann-Whitney tests.

3. Results. When all camps were combined, there was a statistically significant association between the PM_{10} Weekly Maximum level and URD rates based on the Kruskal-Wallis and Mann-Whitney tests, and the Pearson correlation was statistically significant. Although the relationship was not statistically significant in the analyses conducted of the individual camps, the average URD rate increased with each quartile of PM_{10} Weekly Maximum exposure. There was no statistically significant association between PM_{10} Weekly Average exposure and URD rates, although the average URD rate increased with each quartile of PM_{10} Weekly Average exposure.

4. Conclusion. While a causal link cannot be determined from this study, there does appear to be a relationship between PM_{10} levels and URD rates in soldiers deployed to Bosnia in 1997-1998. This contradicts thinking that soldiers are not likely to suffer effects from short term exposure to air particulates. The exposure guidelines in TG 230B should be reevaluated. The effects of air particulates on soldiers should be investigated further as more environmental data becomes available.

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REPLY TO ATTENTION OF

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EPIDEMIOLOGICAL STUDY NO. 29-HE-3841-99 THE RELATIONSHIP BETWEEN AIR PARTICULATE LEVELS AND UPPER RESPIRATORY DISEASE IN SOLDIERS DEPLOYED TO BOSNIA, 1997-98

1. REFERENCES: References used in this report are listed in Appendix A.

2. INTRODUCTION:

a. Background. Air quality has long been associated with respiratory disease; incidents in the 1930s, 40s, and 50s, the most famous of which was the "London Fog" of 1952, clearly demonstrated that high levels of air pollutants were associated with increases in mortality and morbidity[1]. Over the last several years numerous studies in the US and in Europe have shown a remarkably consistent association between air particulate matter and increased mortality[2-15]. The association between air particulates and morbidity has also been examined; significant associations between a variety of health outcomes (hospital admissions, lung function, symptom measures, etc) have been found[2,12,14,17,18].

Both Dockery and Pope[19] and Schwartz[20] conducted reviews and meta-analyses of the studies on air particulate matter in 1994. Dockery and Pope reported that a series of time-series analyses have shown an approximate 1.0% increase in total deaths per day associated with each 10 ug/m^3 increase in PM_{10} (Particulate Matter equal to or less than ten micrometers in aerodynamic diameter) concentration. The effect was greater with cardiovascular disease (1.4% per 10 ug/m^3 PM_{10}) and respiratory disease (3.4% per 10 ug/m^3 PM10)[19]. They also note that the consistency of these estimates across communities suggests that these results are not due to confounding with an unknown or uncontrolled factor and that the mass concentration of the particle mix common to many urban areas, rather than specific chemical species within the mix, may be responsible for the observed associations. In their review of morbidity, Dockery and Pope found that respiratory hospital admissions and emergency department visits increase by approximately 0.8% and 1.0% per $10ug/m^3$ PM_{10} respectively[19]. The increase in emergency department visits and hospital admissions for asthmatics is higher still at 3.4% and 1.9% increase per $10ug/m^3$ PM_{10}[19]. Lung function tests show a modest decrease of approximately 0.15% for Forced Expiratory Volume at one second (FEV_1) or $FEV_{.75}$, and a 0.08% decrease for peak flow, per PM_{10} increase of $10ug/m^3$. Schwartz, examining many of the same studies, concurred. His unweighted meta-analysis yielded a relative risk for mortality of 1.06 (95% CI of 1.05-1.07)[20].

There is little disagreement that particulate air pollution has adverse health effects.

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The question that remains is the degree of this effect, the particulate level at which the effect occurs, and the populations most affected. What is emerging from the literature is that health effects and dose-response relationships are being observed at relatively low concentrations, much lower than what was once considered safe[2,19,21,22]. According to the World Health Organization ,"Recent studies suggest that short-term variations in particulate matter exposure are associated with health effects even at very low levels of exposure. The current databases do not allow the derivation of threshold below which no effects exist. Epidemiological studies are unable to define such a threshold, if it exists, precisely."[21]

Although some longitudinal studies did test the lung function of healthy adults and found acute effects, and hospital usage studies reflect acute effects, many of the measures of morbidity such as emergency department visits, hospital admissions, and asthma medication use tended to focus on sensitive subpopulations (children, the elderly, COPD patients, asthmatics). One notable exception is a study by Chestnut et al.[16] that used NHANES I information and compared pulmonary function with ambient air pollution levels, as measured by Total Suspended Particulates (TSP). This study excluded individuals with serious respiratory disease, and only used individuals who had never smoked. The study was able to control for individual variation by looking for differences in individual's Forced Volume Capacity (FVC) and FEV_1 from their predicted FVC and FEV_1, based on their age, height, weight, and other biological measures. This study showed an effect on both FVC and FEV_1 at between 60 and 80 ug/m^3 of TSP.[16] That an effect would be seen in relatively healthy, non-smoking individuals is of particular importance to the military population. The military has a unique concern for the effect of air pollutants; soldiers are deployed to locations where they may experience higher pollutant levels than they are accustomed to. Any subsequent increase in deleterious health effects can impact a unit's combat readiness. While military service members are generally healthier than the overall US population, deployment conditions may make them prone to the effects of environmental contamination. This hypothesis has not been tested.

b. Study background. The concern about environmentally related diseases among military servicemembers became an issue in the wake of the Gulf War. The current method of evaluating the risk of environmental exposures is to conduct an environmental human health risk assessment (HHRA). However, in HHRAs there is no methodology for evaluating the effect of particulate matter other than to compare the levels to regulatory standards. Given that the literature has clearly shown that health effects occur at levels far below the regulatory standards, this may be an inadequate methodology.

The Department of Defense (DOD) requires the services to conduct medical surveillance, as outlined in Department of Defense Instruction 6490.3. There is a well-established system for gathering this medical data. The military has unique access to service members' medical records, a system that allows for very complete capture of illnesses (service members have a well established system for seeking medical care) and records are kept of each visit to a health care provider. The number of soldiers in the catchment area of a medical treatment facility (MTF) is generally known; consequently,

disease rates can be calculated. There are also requirements to determine potentially hazardous exposures, such as to environmental contaminants, and to conduct overall assessment of troop health (Presidential Review Directive 5). In the wake of the Gulf War, fairly extensive environmental sampling has been conducted in the Balkan theatre. These data are available for analyses. Although the environmental data are more limited than the medical data, the two can be linked in order to conduct analysis. Prior to this study the two databases had not been linked for the evaluation of any particular health outcome. The availability of these databases provides an opportunity to conduct an epidemiological study.

3. OBJECTIVES:

a. To determine if there is a relationship between air particulate levels and upper respiratory disease in soldiers deployed to Bosnia between 1997-1998 at Camps Blue Factory, Comanche, Demi, McGovern, and Tuzla Main.

b. To establish a method for linking military environmental data and military medical data, and identifying areas for improvement in those databases.

c. To determine ways to improve environmental data collection to improve the ability to analyze the data.

4. INVESTIGATORS:

a. MAJ Deborah Hastings, MS

b. MAJ Suzanne Jardine, DVM, MPH, ACVPM.

c. Mr. Brad Hutchens, PE (Air Sampling)

5. METHODS:

a. Study Design: This study was an ecological study. The group for which the data were analyzed was comprised of the soldiers using the medical treatment facilities at Camps Blue Factory, Comanche, Demi, McGovern, and Tuzla Main. These camps were selected because there were both air sampling data and medical data available.

b. Definitions:

(1) Particulate air pollution: Air-suspended mixture of solid and liquid particles that vary in size, composition, origin, and effects.

(2) PM_{10}: Particulate matter with an aerodynamic diameter of less than 10 *u*m.

(3) PM_{10} Weekly Maximum (PM_{10} Max): The highest PM_{10} level recorded at a camp during a given week.

(4) PM_{10} Weekly Average (PM_{10} Avg): The average of all readings taken at a camp during a given week.

(5) Upper Respiratory Disease (URD): The following illnesses and disorders were included in the URD category: acute naso-pharyngitis and sinusitis, tonsillitis, tracheitis, laryngitits, URTI of multiple unspecified sites, polyps, chronic diseases of the tonsils and adenoids, peritonsillar abscess, allergic rhinitis, hay fever external ear, suppurative and non-supperative otitis media and eustachian tube disorders, unspecificed otitis media, mastoiditis and related conditions, other disorders of tympanic membrane, other disorders of middle-ear and mastoid, vertiginuous syndromes and other disorders of the vestibular system, otosclerosis, other disorders of the ear, deafness, and any other diseases of the upper respiratory tract.

c. *Data Sources*:

(1) Sick call data were collected by the MTFs located at the respective camps. The Disease Non-Battle Injury (DNBI) data were collected from ten separate MTFs in Bosnia. The DNBI data were compiled by week. The initial DNBI data included hospital or clinic location, associated administrative data, the catchment population, date, disease type, number of initial visits, rate of initial visits per 100 soldiers, days of light duty and days of lost duty, as well as follow-up visits. The DNBI data available were very general with illnesses were grouped into broad categories. The data from 1997 and 1998 had two respiratory disease categories: upper and lower. Only the data from five of the ten MTFs in Bosnia were used in this study. The other five locations either could not be matched with air sampling data, or closed before 1997, and therefore did not have data specifically on URDs.

(2) Air sampling data was collected by the Deployment Environmental Surveillance Program at the United States Army Center for Health Promotion and Preventive Medicine. The database contained data on PM_{10} levels in ug/m^3, by sampling location. There were also data on other contaminants, such as Semi-Volatile Organic Compounds (SVOCs), Volatile Organic Compounds (VOCs), metals, and pesticides, but the data were severely limited, and consequently could not be used in this study. The data were merged with DNBI data by week of the study. PM_{10} readings were converted into two variables, one of which reflected the average concentration of PM_{10} for the week, and the second of which reflected the maximum PM_{10} concentration for the week. Because of limited sampling, the amount of data available varied widely by camp. In some cases only one sample was collected during the week, so that value would appear as both the PM_{10} average value and the PM_{10} maximum value. In other cases, as many as ten samples were collected in a single week so the values for PM_{10} average and PM_{10} maximum would be different. Additionally, PM_{10} maximum reflects the maximum value measured, not necessarily the maximum level to which the soldiers were exposed, since there may have been several days in a week not sampled. Details on the air sampling can be found

in the USACHPPM report "Interim Environmental Surveillance Assessment No. 47-EM-7678-96, Environmental Surveillance Summary for Operation Joint Endeavor (OJE) and Operation Joint Guard (OJG). Bosnia-Herzegovina, February 1996-June 1998".

(3) The data that were used were limited to the weeks and locations where both sick call data and PM_{10} data were available. Data were analyzed overall, and for each camp separately. This was necessary because camps were sampled with different frequencies, during different weeks, and varied in other ways, such as environmental conditions and weather. Analyzing each camp separately controlled for some potential confounders.

d. Analysis.

(1) At each camp, each week in which sampling was conducted was assigned to an exposure group based on the quartile into which the PM_{10} Weekly Maximum for the week fell. The quartile cutpoints were determined using the range of exposures at all five of the camps, so that assignment to exposure groups was consistent at the five camps. This was to ensure that the definition of high or low exposure was consistent between the camps, since some camps routinely experienced higher PM_{10} exposures. The four exposure groups were compared for differences in the URD rate using the Kruskal-Wallis test. A second analysis was conducted by collapsing the exposure groups into just two categories (upper and lower fiftieth percentile) and comparing the two groups using the Mann-Whitney test.

(2) The same analysis was conducted breaking the weeks into exposure groups based on the PM_{10} Weekly Average.

(3) The average URD rate for each quartile of exposure was graphed using both methods of exposure assessment (PM_{10} Weekly Average and PM_{10} Weekly Maximum); the same was done for the two exposure group analysis (upper and lower fiftieth percentile).

(4) URD rates were correlated with PM_{10} Weekly Average and PM_{10} Weekly Maximum quartile of exposure, and upper or lower fiftieth percentile of exposure.

(5) The effect of seasonality was not tested since no sampling was conducted in the fall, and only three of the 75 weeks when sampling was conducted were in the winter months.

6. RESULTS:

a. Breakdown of sampling weeks by season. The majority of the sampling was conducted during the spring and summer months. The breakdown by season is shown in Table 1.

Table 1: Number of Weeks Sampled by Season

Season	Number of Weeks Sampled
Winter (Dec, Jan, Feb)	3
Spring (Mar, Apr, May)	58
Summer (Jun, Jul, Aug)	14
Fall (Sep, Oct, Nov)	0

b. Summary Air Data: The low, high, and mean PM_{10} Weekly Maximum and PM_{10} Weekly Averages are shown in Table 2. The PM_{10} Average Mean is the average of all the PM_{10} Weekly Averages, and the PM_{10} Maximum Mean is the average all of the PM_{10} Weekly Maximums. In some weeks at some camps, only one sample may have been taken. Consequently, PM_{10} Weekly Maximum and PM_{10} Weekly Average values may be the same. Camp Comanche had the highest point readings as well as the highest averages of both PM_{10} Weekly Averages and PM_{10} Weekly Maximums. Camp Demi had the lowest averages; however Camp Demi only had five weeks in which air sampling was conducted.

Table 2: Summary Air Data by Camp (PM_{10} in ug/m^3)

	PM_{10} Weekly Average				PM_{10} Weekly Maximum		
Camp	Weeks*	Low	High	Mean	Low	High	Mean
Blue Factory	24	28.0	120.6	68.7	28.0	144.2	86.8
Comanche	21	33.6	338.7	85.4	33.6	338.7	102.6
Demi	5	25.0	57.4	45.2	25.0	90.4	68.1
McGovern	5	27.8	108.6	49.9	29.4	108.7	70.0
Tuzla Main	20	38.5	152.9	72.3	38.6	231.4	90.4
All Camps	75	25.01	338.7	75.5	25.0	338.7	92.9

*Indicates number of weeks in which at least one day of sampling was conducted at that location.

c. Upper Respiratory Disease (URD) Rates. The average rate for each camp in the study was calculated by averaging the weekly rates for the weeks for which PM_{10} data were available. The rates are reported in Table 3. The camp with the highest average URD rate was Camp Blue Factory, which was also the camp for which the most data

were available. The lowest rate each camp experienced is shown in Min, the highest rate each camp experienced is shown in Max, and the mean rate is shown.

Table 3: Summary URD Weekly Rates (Per 100 soldiers) by Camp

Camp	Weeks*	Min	Max	Mean
Blue Factory	24	0	6.1	2.7
Comanche	21	0	3.1	1.5
Demi	5	.38	2.1	1.2
McGovern	5	.67	5.0	2.5
Tuzla Main	20	.60	3.5	1.8
All Camps	75	0	6.1	2.0

*Indicates number of weeks for which data was available

The average URD rate per quartile of exposure is shown in Table 4 for the exposure to the PM_{10} Weekly Maximums and Table 5 for the PM_{10} Weekly Averages. The quartile cutoff points are shown in Table 6. The number of weeks in each quartile of the weekly maximum exposure is roughly equal in each of the camps with the exception of Demi and McGovern which experienced no weeks during the study period with exposure levels in the fourth (highest) quartile of exposure. The quartile for PM_{10} Weekly Average exposure is also roughly equal with the exception of Demi and McGovern where there were no weeks where the PM_{10} Weekly Average exposure was in the third or fourth quartiles. Generally, the average URD rate increased with quartile of PM_{10} Weekly Maximum exposure, most notably at Blue Factory and in a combined analysis of all camps. The trend was not as clear for the quartiles of PM_{10} Weekly Average exposure. This is displayed graphically in Figures 1 and 2. The results of the statistical analyses are discussed in paragraph d.

Table 4: Average URD Rate by PM_{10} Weekly Maximum Quartile

Quartile	Blue Factory	Comanche	Demi	McGovern	Tuzla Main	All Camps
1	.262 (5)	1.18 (5)	1.14 (1)	2.29 (3)	1.93 (5)	1.93 (19)
2	1.95 (6)	1.25 (5)	.47 (2)	.67 (1)	1.44 (5)	1.41 (19)
3	2.73 (6)	2.05 (5)	2.03 (2)	4.96 (1)	1.77 (5)	2.34 (19)
4	3.4 (7)	1.36 (6)	NA	NA	2.05 (5)	2.34 (18)

() = number of weeks included in the average

Table 5: Average URD Rate by PM_{10} Weekly Average Quartile

Quartile	Blue Factory	Comanche	Demi	McGovern	Tuzla Main	All Camps
1	2.8 (5)	.87 (4)	.85 (2)	1.9 (4)	1.5 (4)	1.7 (19)
2	2.9 (4)	1.7 (5)	1.5 (3)	5.0 (1)	1.8 (5)	2.1 (18)
3	2.2 (7)	1.5 (6)	NA	NA	1.8 (6)	1.8 (19)
4	3.0 (8)	1.6 (6)	NA	NA	2.0 (5)	2.3 (19)

()= Number of weeks included in the average

Table 6: PM_{10} Quartile Cutpoints

Quartile	PM_{10} Weekly Maximum (ug/m^3)	PM_{10} Weekly Average (ug/m^3)
1	<58.57	<42.19
2	60.1 to <74.54	42.19 to <64.17
3	78.56 to <107.56	64.17 to <81.75
4	> 107.56	$\geq$ 81.75

Figure 1: URI Rates By PM10 Weekly Maximum Exposure Quartile

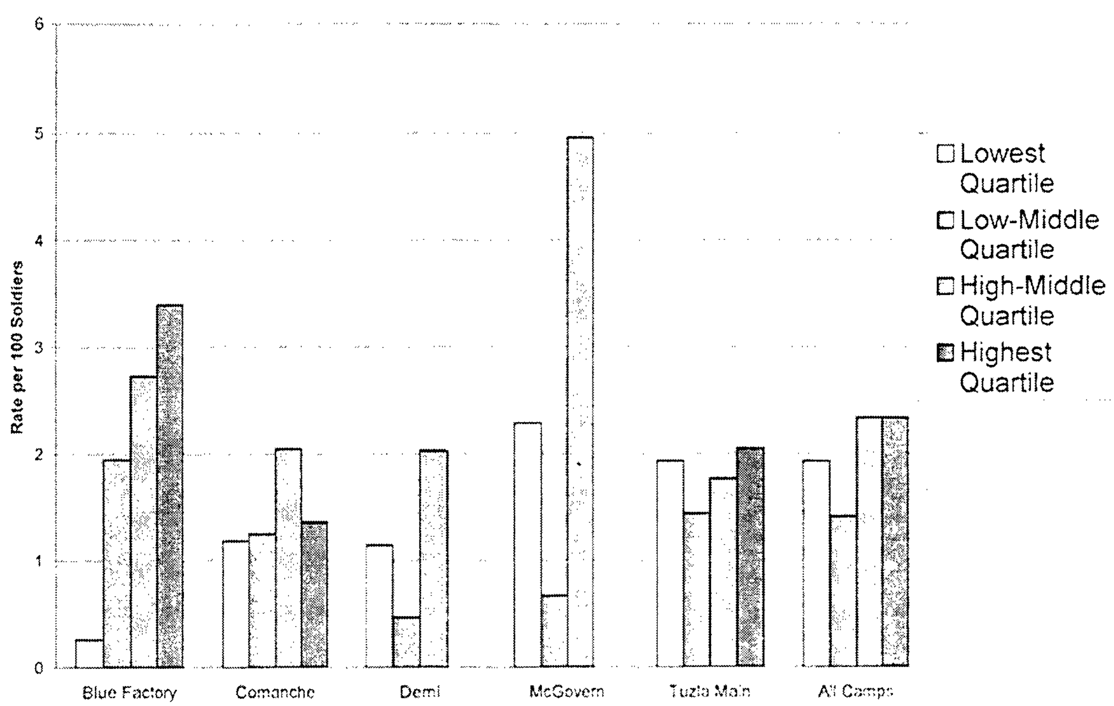
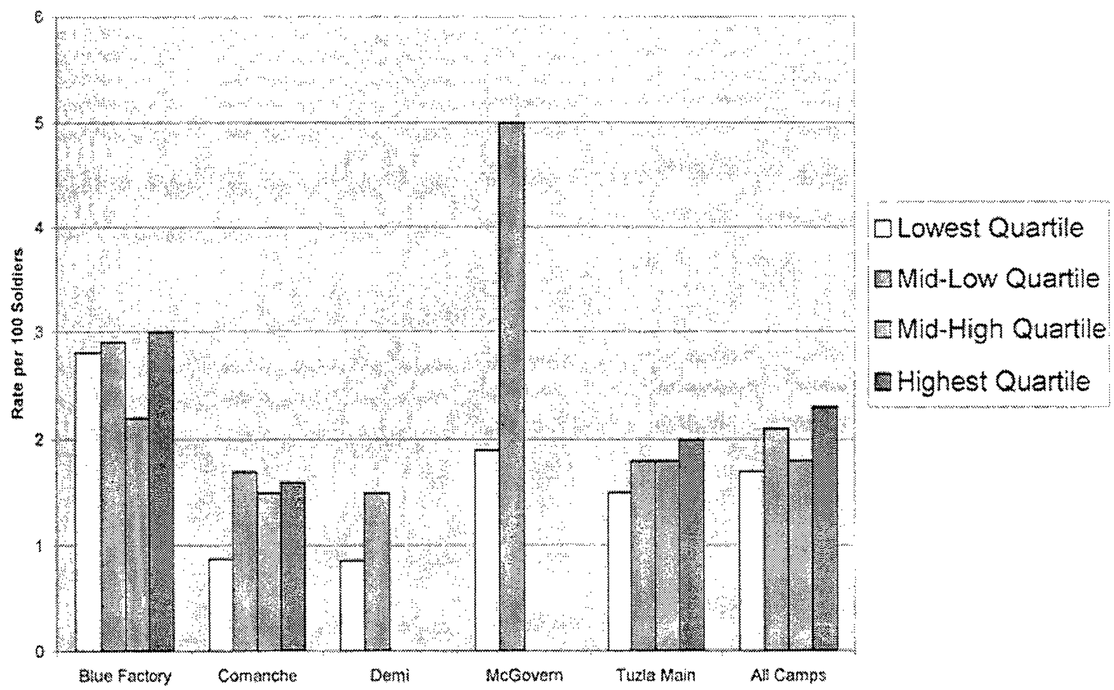


Figure 2: URI Rates By PM10 Weekly Average Exposure Quartile



The average URD rates for the weeks in the upper and lower fiftieth percentile of exposure to the PM_{10} Weekly Maximum levels and PM Weekly Average levels are shown in Tables 7 and 8. The fiftieth percentile cutpoints are shown in Table 9. The number of weeks in which the maximum weekly exposure was in the top half and lower half were roughly equal at all camps except McGovern. The average URD rates were higher at all of the camps in the weeks when the maximum exposure was in the upper fiftieth percentile. The data on the weekly averages were limited, as two camps had no weeks in the study when the exposure was in the upper fiftieth percentile. Of the remaining three camps, the average URD rate was higher when the exposure was in the upper fiftieth percentile at two of the camps and when all the data were combined. This is displayed graphically in Figures 3 and 4.

Table 7: Average URD Rate by Upper and Lower Fiftieth Percentile of PM_{10} Weekly Maximum

Quartile	Blue Factory	Comanche	Demi	McGovern	Tuzla Main	All Camps
Lower	2.25 (11)	1.22 (10)	1.14 (3)	1.89 (4)	1.68 (10)	1.67 (37)
Upper	2.34 (13)	3.09 (11)	1.68 (2)	2.03 (1)	4.96 (10)	1.91 (38)

()= number of weeks included in the average

Table 8: Average URD Rate by Upper and Lower Fiftieth Percentile of PM_{10} Weekly Average

Quartile	Blue Factory	Comanche	Demi	McGovern	Tuzla Main	All Camps
Lower	2.8 (9)	1.3 (9)	1.2 (5)	2.5 (5)	1.7 (9)	1.9 (37)
Upper	2.6 (15)	1.6 (12)	NA (0)	NA (0)	1.9 (11)	2.1 (38)

() = number of weeks included in the average

Table 9: PM_{10} Fifty -Percentile Cutpoints

Quartile	PM_{10} Weekly Maximum 50%-tile Cutpoint (ug/m^3)	PM_{10} Weekly Average 50 %-tile Cutpoint (ug/m^3)
Lower Exposure	<74.55	<64.17
Higher Exposure	$\geq$ 74.55	$\geq$ 64.17

Figure 3: URI Rate by Upper vs. Lower 50th Percentile Exposure (PM10 Weekly Maximum)

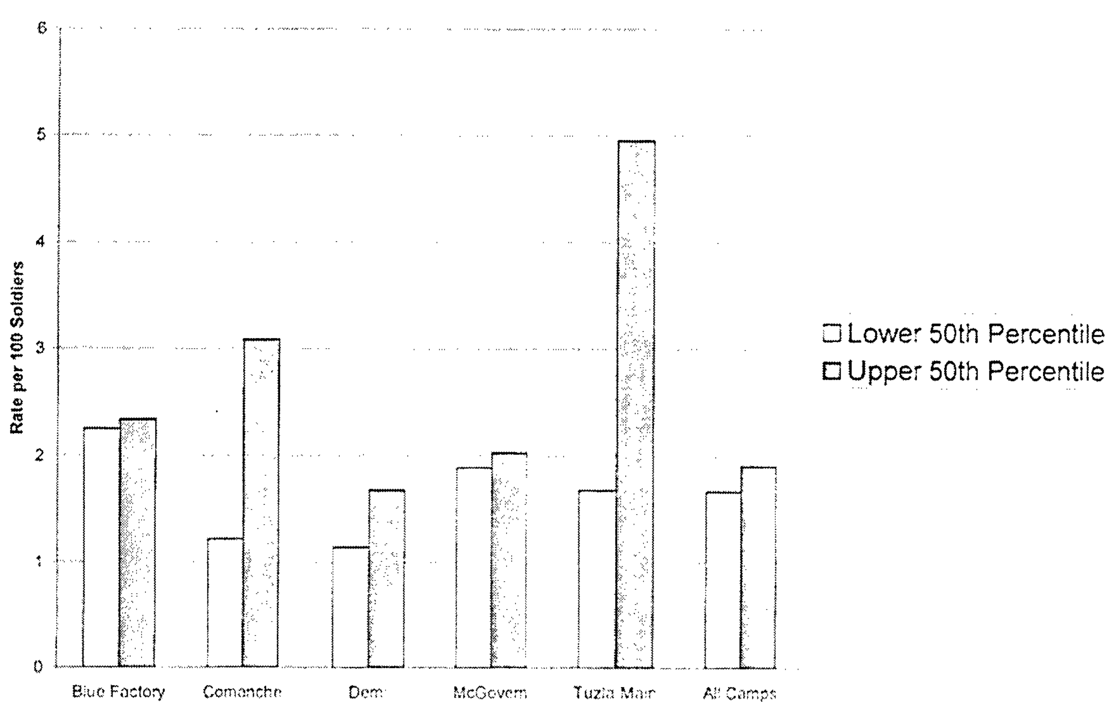
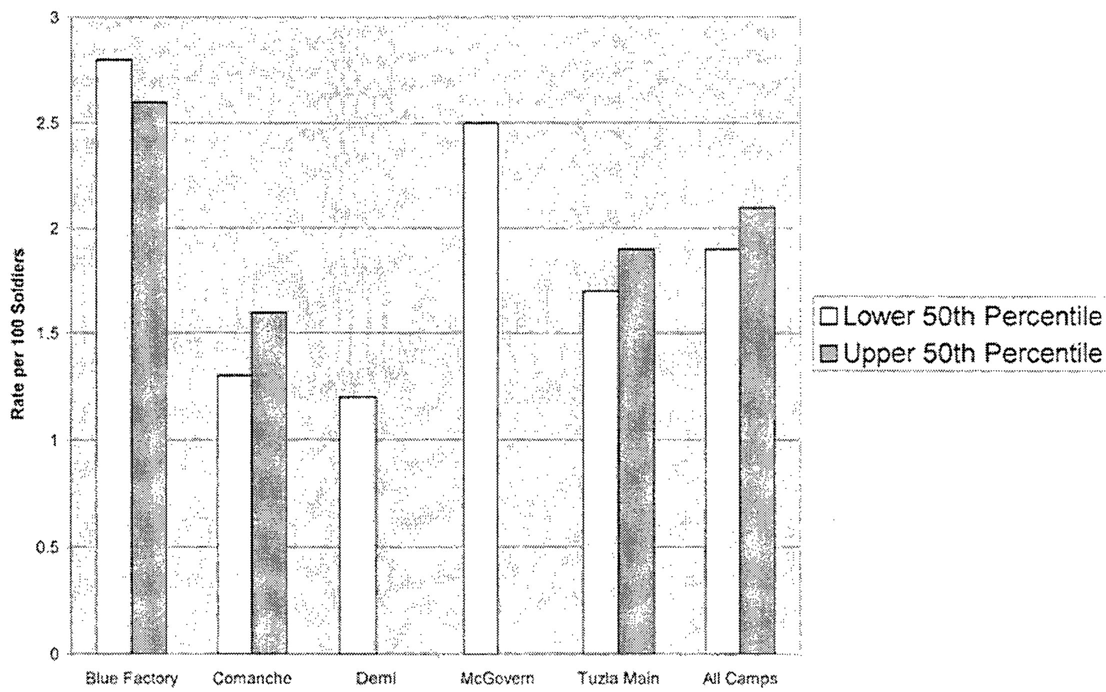


Figure 4: URI Rates by High vs. Low Exposure (PM10 Weekly Average)



d. Statistical Analysis. The Pearson correlation coefficients are displayed in Table 10. There is a statistically significant correlation between URD rates and a PM_{10} Weekly Maximum exposure by upper or lower fiftieth percentile at Camps Demi and McGovern. When all camps were combined the correlation between URD rate and PM_{10} Weekly Maximum Quartile and PM_{10} Weekly Maximum Upper or Lower Fiftieth Percentile was statistically significant. The results of the Kruskal-Wallis test are displayed in Table 11. None of the camps had a statistically significant association between URD rates and PM_{10} Weekly Maximum or PM_{10} Weekly Average (using $p < .05$ as the threshold for statistical significance). However, when the data for all camps were combined, (providing a larger number of weeks for analysis and thus increasing the statistical power) the differences among the URD rates by PM_{10} Weekly Maximum quartile were statistically significant, as was the difference when the exposure groups were defined by upper and lower fiftieth percentile. When the comparisons were based on the PM_{10} Weekly Average the differences were not statistically significant. Two of the camps could not be analyzed based on weekly average exposure in the upper or lower fiftieth percentile, because they had no weekly average exposures in the upper fiftieth percentile.

Table 10: Pearson Correlation Coefficients and p-value of URD Rates with Exposure Levels (Quartiles and Upper and Lower Fiftieth Percentiles of PM_{10} Maximum Values and PM_{10} Weekly Averages)

Camp	PM_{10} Weekly Maximum (Quartiles)	PM_{10} Weekly Average (Quartiles)	PM_{10} Weekly Maximum (50%-tile)	PM_{10} Weekly Average (50%-tile)
Blue Factory	.277 (.095)	.301 (.077)	.038 (.430)	-.075 (.365)
Comanche	.165 (.237)	.246 (.141)	.282 (.107)	.143 (.268)
Demi	.639 (.123)	.437 (.231)	.927 (.012)	Could not test
McGovern	.535 (.177)	.853 (.033)	.853 (.033)	Could not test
Tuzla Main	.107 (.327)	.182 (.222)	.155 (.258)	.123 (.303)
All Camps Combined	.203 (.041)	.149 (.101)	.283 (.007)	.060 (.305)

* Gray shading indicates statistical significance at the 0.05 level (1-tailed)

Table 11: Results of Kruskal-Wallis and Mann Whitney Tests (p-value) Comparing URD Rates by Exposure Levels (Quartiles and Upper and Lower Fiftieth Percentiles of PM_{10} Maximum Values and PM_{10} Weekly Averages)

Camp	PM_{10} Weekly Maximum (Quartiles)	PM_{10} Weekly Average (Quartiles)	PM_{10} Weekly Maximum (50%-tile)	PM_{10} Weekly Average (50%-tile)
Blue Factory n=24	.321	.809	.173	.682
Comanche n=21	.556	.658	.314	.508
Demi n=5	.165	.564	.083	Could not test
McGovern n=5	.202	.157	.401	Could not test
Tuzla Main n=20	.554	.891	.481	.656
All Camps Combined n=75	.047	.672	.034	.824

*Gray shading indicates statistical significance at the 0.05 level

8. DISCUSSION:

a. Interpretation. This study found that when all the camps were combined there was a statistically significant association (at the $p < .05$ threshold) between URD rates and PM_{10} Weekly Maximums. This was noted in both the Kruskal-Wallis test, and is shown in the correlation between PM_{10} Weekly Maximums and URD rates. The fact that the association was not statistically significant by the Kruskal-Wallis and Mann-Whitney tests at the individual camps may be explained by the extremely small number of weeks sampled at most of the camps. This is supported by the statistically significant correlations at Demi and McGovern between URDs and PM_{10} Weekly Maximums (upper and lower fiftieth percentile). It is noteworthy that the third quartile and fiftieth percentile cutpoints are at levels that the recent literature indicates an effect may be seen (between 60 and 70 ug/m^3); this level is lower than previously suspected. The results of this study appear to contradict the thinking that healthy soldiers are not likely to be effected at these levels. Interestingly, the overall URD rates during the study weeks were fairly low. This is most likely due to the majority of the sampling being conducted in the summer months.

It is important to note that the camps analyzed in the study were not necessarily the camps with the highest PM_{10} levels. For example, Camp Eagle, which was not analyzed, (it closed before 1997, and therefore data on URDs were not available) experienced PM_{10} levels nearly triple what some of the analyzed camps experienced. In comparison to cities in the US, soldiers are being exposed to higher PM_{10} levels (both average and maximum levels) than all but the worst metropolitan areas in the US. The mean of the PM_{10} Weekly Average at Tuzla Main (based on data from 20 weeks) was higher than all but one metropolitan area for which data was available in 1998[23]. The study camp's mean PM_{10} Weekly Averages exceeded the PM_{10} National Ambient Air Quality Standard (Annual Average of 50 ug/m^3)[24] at three of the five camps. The NAAQS 24-hour standard of 150 ug/m^3 was also routinely violated. Unlike most people living in the US, soldiers do not have the opportunity to mitigate the effects by altering activity level or going inside a building where the levels may be reduced. Since the literature has clearly indicated that cities with particulate levels lower than what many camps are being exposed to are suffering increased morbidity and mortality, this is a concern that should be addressed.

The fact that the relationship appears to be more strongly between the PM_{10} Weekly Maximum than with PM_{10} Weekly Average has many potential explanations. The quartile cutpoints are higher for PM_{10} Weekly Maximum, so it represents higher exposure to air particulates. Another potential explanation is that due to the nature of the sampling, where a maximum and average might be the same during a given week, the PM_{10} Weekly Maximum might better represent random sampling of the week (although the sampling was not random), while the PM_{10} Weekly Average is more likely to be biased by the unequal numbers of samples taken at different camps and in different weeks. This illustrates the need for systematic sampling to be conducted. Although the literature has shown that there is frequently a "lag effect" seen in the health effects caused by air particulates, that lag could not be analyzed in this study because sick call rates were reported by week. Consequently, the "lag" could not be defined; there was no way to

determine the time between the exposure to air particulates and the onset of illness, other than to know that the illness occurred in the same week as the particulate exposure. Consequently, the lag effect was not investigated.

The outcome investigated in this study was URDs. As defined in this study, "URD" encompasses a wide range of symptoms and syndromes. This could decrease the sensitivity of the study, as the effect of PM_{10} exposure on a specific outcome (ie pharyngitis) would not be detected. The endpoint measured in this study was a visit to a health care provider. The severity of the URD was not investigated in this study. Severity could be measured by the need for medication, hospitalization, or being put on quarters (rest). However, visits to a health care provider may be a useful measure, as they can be seen as a measure of when the illness effects the servicemember to the degree that he seeks medical care. This is similar to the effect measured by some of the civilian studies that investigated increased emergency room or outpatient visits, but may detect effects at lower levels than the civilian studies, due to the immediate access to free medical care enjoyed by servicemembers.

b. *Study strengths.*

(1) The primary strength of this study is that it links medical surveillance data to environmental data to investigate a specific health outcome, based on real exposures and using epidemiological methodology, instead of merely conducting a risk assessment which relies on toxicology data that may have severe limitations, and on exposure assumptions.

(2) Another strength of this study is that it has a fairly good capture of cases. Although some less acute cases may have been missed because the soldier sought medical assistance at lower echelons of care, certainly the more severe cases were captured in the surveillance system. The reporting methodology was consistent among MTFs.

c. *Study limitations.*

(1) The primary limitation in this study is the lack of "analyzable weeks". There were only 75 total weeks available for analysis; no camp had more than 24 weeks. The effect of PM_{10} levels on URDs in healthy populations is likely to be small. Consequently, it is quite likely that this study lacked the statistical power to detect differences in URDs rates caused by air particulates if, in fact, the effect is real. As discussed above, URD, as defined in this study encompasses a wide range of symptoms and syndromes. Looking at a more specific outcome might be more revealing.

(2) The other major limitation of this study was the exposure classification. The environmental data available for this study, besides being too infrequent to provide enough statistical power, may not have been adequate to truly characterize soldier's exposure to PM_{10}. If only one sample was taken at a camp per week, it is impossible to know if that level is the average, the maximum, or the minimum that soldiers were

exposed to. Equally important is that the methodology is not consistent from week to week or from camp to camp. Consequently, the environmental sampling was essentially "grab" sampling and not systematic or random sampling.

(3) Soldiers who were seen at a given MTF may or may not have been exposed to the levels of PM_{10} that were detected at that location.

(4) The calculation of the rates was based on the troop strength at the camp where the MTF was located. This may not be a good measure, as soldiers living and working elsewhere may have been seen at the MTF. Additionally, troop strengths varied over time, and so the weekly troop strength reported was an average for the week. It may not accurately reflect the catchment area for the MTF.

(5) Winter months were not included in the study (other than three weeks) because environmental data was not available for winter weeks. While only sampling during the summer months does allow for better control of weather as a confounder, it is possible air particulate matter may have a greater or lesser effect on URDs in the winter. This study cannot test that hypothesis.

(6) This study did not control for confounding by other air pollutants. However, the literature has indicated that the particulate matter is one of the primary "culprits" when other potentially confounding air pollutants are controlled for[7].

(7) This study, like all ecological studies, is prone to the ecological fallacy. However, the camps were essentially being compared to themselves, which helps prevent the effect. Unless there are other factors that vary with air particulate matter and also contribute to upper respiratory disease, the study is not likely to suffer from the ecological fallacy. The possibility that there is an unidentified covariate cannot be ruled out.

9. **CONCLUSIONS.** While strong conclusions cannot be drawn from this study due to the limitations discussed above, there does appear to be a relationship between PM_{10} levels and URD rates in soldiers deployed to Bosnia in 1997-1998. The effects of air particulates on soldiers should be investigated further as more environmental data becomes available.

Perhaps more important than the results of the study itself was the demonstration that the environmental and medical data from a theatre of operations can be linked in a meaningful way and used for epidemiological studies. By conducting this study, some of the data shortfalls have been identified, and can be corrected, which will allow for more sophisticated studies to be conducted in the near future.

10. RECOMMENDATIONS/FUTURE STUDIES.

a. *Surveillance.* The primary recommendation from this study is that environmental surveillance be conducted in a manner that allows the data to be linked with medical surveillance data more easily. Exposures need to be documented more thoroughly; this requires conducting more extensive sampling to allow exposure to air contaminants to be more accurately characterized over time. This will require additional resources, including personnel.

b. *Reevaluate TG 230B.* Although not strongly conclusive this study suggests that servicemembers may be experiencing a higher rate of URDs when PM_{10} levels are over ~70 ug/m^3. Given this findings, in conjunction with recent findings in the scientific literature, the PM_{10} exposure guidance for servicemembers established in Technical Guide 230B should be reevaluated.

c. *Future Studies.* In the future, as the ability to link individuals with exposure data becomes possible, a prospective cohort study on the effects of air particulate matter on deployed soldiers jointly with the Deployment Environmental Surveillance Program (DESP) should be conducted. More immediately, the methodology of this study should be repeated in other theatres (such as Southeast Asia) where more environmental data is available, and the results compared with this one, to determine if the findings are consistent. Those studies should also investigate enpoints that measure the severity of the effect, such as lost duty time. Although that could be done with the data available for this study, the time and effort would be better spent on a study where the environmental data is more comprehensive and systematic. Such data is currently available within DESP from other theatres, and from more recent sampling in the Balkan theatre, and should be utilized.

d. *Protective measures.* Currently there are limited actions that can be taken by deployed soldiers when air particulate levels reach unhealthy levels. If future studies establish a link between air particulate levels and illness among deployed soldiers, time and research should be devoted to developing protective measures. This does not necessarily require equipment changes, but may take the form of developing an index similar to heat and cold indexes that prompt behavioral changes, and providing commanders better risk assessment and management information. Additionally, commanders should be educated on the potential effects on their soldiers, so they can take measures to avoid exposure when mission permits.

APPENDIX A
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